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SALVAGE OF STANDING BEETLE-KILLED YELLOW PINE BY MILLING

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INTRODUCTION

During the past fifteen years extensive barkbeetle epidemics have resulted in great commercial losses in various localities in the western United States. In a large measure these beetle losses have resulted from depredations of the western pine beetle (Dendroctonus brevicomis Lec.) in stands of the western yellow pine (Pinus ponderosa Laws.). This species outranks all other western pines in both quantity and extent of range, and since its stumpage value is high it is the principal commercial pine of this region. Consequently the problem of salvaging beetle-killed timber is of immediate interest to timber owners throughout the west.

Aside from the commercial standpoint the salvage of beetle-killed timber is desirable as a conservation measure, since it is possible to utilize the lumber from these trees for a variety of purposes in which it is on a par with green stock. Furthermore, the removal of dead trees from the forest is a fire-prevention measure of some importance.

At least two attempts at salvaging beetle-killed yellow pine have been made during the past decade, but it is difficult to judge the success of these operations, since the stock was not followed through the milling operations and no records are therefore available as to the amount of degrading or cull.

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One of these attempts was made by a large lumber company in northern California, 1922 to 1925. This salvage operation followed a large beetle-control project which was conducted from 1920 to 1924 on an area of 45,000 acres. During the control operations a total of 6,370 beetle-killed trees, with a volume of 5,539 m.b.m., were treated. Subsequent to the control work this area was logged and many of the treated beetle-killed trees, which had been felled and barked, were salvaged and milled along with the green timber. No separate records were kept of the amount or quality of this salvaged stock.

Another instance of the salvage of beetle-killed yellow pine, though on a smaller scale, was the milling of about 200 m.b.m. in 1924 and 1925 on the Kaibab Forest of Arizona. Both standing trees and trees felled in control operations were milled. Only the trees of larger diameters were salvaged, and of these only the heartwood was utilized.

At the present time a combined salvage-control project of a size not hitherto attempted is in progress on the Modoc Forest of northern California. In this project the objective is to control the beetles by logging and milling the trees which have been attacked. So far only the trees infested at the time of logging have been salvaged on this project.

However, none of these operations has yielded data upon which an analysis of degrading and cull of beetle-killed stock could be based.

A study of the deterioration of beetle-killed trees felled in control work was made by J.S. Boyce in 1921 in the yellow pine forests of southern Oregon.[1] This study determined the cause and rate of deter-

[1]Boyce, J.S.—"The Deterioration of Felled Western Yellow Pine on Insect Control Projects." U.S.Dept.Agr.Bul.No.1140,1923.

ioration and the percentage of cull in such trees. It did not, however, include standing beetle-killed trees, which are of more commercial importance than partially-burned treated trees, since they represent a greater available volume.

In the present paper the problem of the salvage of standing beetle-killed yellow pine is considered. The study reported herein was made possible by a small milling operation in Jackson County, southern Oregon, with which the writer was connected. While the data collected are insufficient to form the base for a thorough discussion of the salvage of beetle-killed trees, they do shed additional light upon some phases of the problem.

METHOD OF COLLECTING DATA

The study was made during the process of logging an area of 80 acres during the period May 9 to July 20, 1928. The logged area had been cruised annually by field men of the Bureau of Entomology for a period of eight years previous to logging. From these cruises the beetle losses each year were definitely known, and each beetle-killed tree was marked with the year and season of its attack. This accurate dating of the death of the trees was of great value in determining the period of time between the death and milling of each tree utilized. As will be seen, it bears a direct relation to the amount of deterioration and of cull.

The beetle-killed trees were salvaged in the regular operation of logging and milling the green timber. Each killed tree on the logged area was examined by the writer previous to felling. Examinations consisted of opening up the lower trunk with an ax sufficiently to disclose the amount of deterioration. If the tree was found to be merchantable it was marked for cutting and the date of death was recorded.

In this logging operation the logs were yarded and loaded by horses and hauled by truck. This method requires that the trees be bucked into log lengths before being bunched for loading. All the beetle-killed trees were bucked into standard 16-foot log lengths. The writer scaled each log in the woods with the Scribner Decimal C scale, according to standard commercial practice. In scaling, the average diameter under the bark of the small end of the log, and the average diameter of the heartwood at the same end, were scaled separately. This gave the total board-foot content of the entire log, and also the b.f. content of the heartwood alone. Cull was not recognized in scaling, since crooked trees and those containing unmerchantable stock were not felled. The gross scale given in Table II is the actual merchantable volume of each tree and includes both blued sapwood and unstained heartwood.

It was optional with the owner of the timber to sell the beetle-killed trees on either of the two following plans: the unstained heartwood only at the same price per m.b.m. paid for green logs; or the gross volume, including stained sapwood, at 33⅓ less than the green pine rate. Because the logs were sold delivered at the mill it was to the best interests of the owner to sell at the reduced price and deliver the gross volume, since the cost of logging was determined by the full scale, and the differential between cost of production and selling price on this basis resulted in a greater margin of profit.

It was unnecessary to check the logs through the mill, since the mill operator did not cull the degraded stock nor attempt to grade the unstained heartwood deparately. A part of the total sawn volume of the beetle-killed lumber was utilized for "stickers" in the stacking yard, and the rest was either graded to "box", or sold locally for siding.

PHYSICAL CHARACTERISTICS OF BEETLE-KILLED TIMBER IN HANDLING

In the woods handling of beetle-killed trees there are certain characteristics which differentiate them from green timber. These changed conditions result from the partial deterioration of the trees previous to felling. In some respects they facilitate the handling, while in others they are a real hindrance. Some of the beneficial aspects are the absence of heavy foliage, making necessary less swamping around the felled trees; and lighter logs, due to partial seasoning, with consequent lower yarding, loading and hauling costs. The adverse conditions are greater likelihood of breakage in felling, toughness in bucking, and wet, slippery surface of the sapwood. The breakage hazard in felling beetle-killed trees is greater, and a high percentage of these trees throw their tops even on smooth ground. However, this tendency is confined to the upper trunk, which is partially dried out. The lower trunk is moist and will withstand heavy stresses in felling, though because of this condition bucking is more difficult. Most beetle-killed trees throw the bark from the main trunk when felled. This action bares the wet and slick surface of the sapwood, resulting in difficulties in loading, since the tendency to slip on the skids and bunks is increased. However, the yarding of such logs is facilitated because of this slick surface.

An analysis of item cost of the separate operations in logging beetle-killed trees shows that they can be handled by the method employed in this operation at about 20% less cost than green stock. This saving is due to the lighter weight and occurs in the yarding and hauling operations.

CAUSES AND RATE OF DETERIORATION

The principal causes of deterioration in beetle-killed trees are fungi, which develop in both sapwood and heartwood; and checking, induced by the drying out of the surface wood. These first defects are followed by injury from wood-boring insects, which excavate food burrows or "worm holes" in both heartwood and sapwood.

These trees do not deteriorate greatly until after the second season of exposure. During the first two seasons deterioration is confined chiefly to bluing of the sapwood and to a pronounced drying of the upper trunk, resulting in check. Blue sap-stain is not considered a defect sufficient for cull, since discolored wood can be used for a variety of purposes. However, this discoloration does degrade the lumber, because of popular prejudice against stained wood. Checking of the upper trunk is a serious defect and results in cull of the affected section.

After the second season of exposure beetle-killed trees deteriorate with extreme rapidity, so that after the third or fourth season the sapwood may be commercially a complete loss through decay, and the heartwood badly worm-eaten.

The amount of salvage from trees in such condition is so low as to render impracticable their utilization under present standards of lumber production and usage. In this operation no trees which had been dead longer than two seasons contained enough merchantable stock to defray the expense of logging.

During the two years immediately preceding logging there was killed by beetles on the 80 acres of logged area to total of 47 trees, containing a volume of 51,430 board feet. Of this number 27 trees, containing a volume of 22,450 board feet, were killed in 1926, and 20 trees, with a volume of 28,980 board feet, were killed in 1927. The season of attack and death was known, as well as the year for each tree, so it was possible to place the trees in four groups, i.e., those felled in the summers of 1926 and 1927 and in the falls of the same years.[2] Thus the

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[2] "Attack season" indicates date of attack, as 1926S (summer) shows that the tree was attacked and killed by the summer brood or generation of beetles as contrasted with 1926W (winter), which means that the tree so designated was attacked by the winter brood of 1926. In this region summer broods attack from early May to the middle of August, whereas winter broods attack from the latter date until late in October.

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deaths of the trees were dated in four separate periods, ranging from a minimum of eight months to a maximum of twenty-four months previous to logging. These data are shown in tabular form in Table I. The important feature of this table is the increase in cull volume of trees killed in 1926.

The deterioration of these trees has a close relation to the length of time elapsing between death and logging. In this case, 52.3% of the volume killed by summer broods of beetles in 1926 was culled and also 26.8% of that killed by the winter brood of that year. In direct contrast was the low cull percentage of trees killed in 1927, the total amount, 13.6%, occurring in trees killed by the summer brood. There was no cull from trees attacked by the winter brood of 1927. Therefore the rate of deterioration of these trees, as shown by percentage of cull, was none for those attacked in the late summer of 1927 and exposed for 8 months; 13.6% for those attacked in the spring and early summer of 1927; and 26.8% to 52.3% for those attacked by the summer and winter broods, respectively, of 1926. These data also indicate that the greatest deterioration occurs during the growing seasons.

Fig. 1 is a diagrammatic chart based on Table I, and illustrates the rate of deterioration of the trees killed by beetles for the two years preceding logging.

AMOUNT OF DETERIORATION AND CULL

While blue sap-stain is not considered a defect, it does degrade the lumber and in this sense is a form of deterioration. Sap-stain closely follows beetle attack and is usually well developed throughout the sapwood by the end of the first season. Blue-staining is practically confined to the sapwood, the fungus which causes it rarely attacking the heartwood. It is practically impossible to judge accurately the amount of sap-stain in a standing tree, though it is easily scaled after the tree is felled and bucked. Since the entire sapwood of beetle-killed trees is usually badly stained, the amount of sapwood becomes the basis for estimating the volume of this form of deterioration. The volume of the sapwood varies greatly, even in trees within close diameter limits, but is relatively much greater in small-diameter yellow pine, commonly known as "blackjacks". In these small trees it may represent as much as 90% of the total volume.

In order to determine the amount of blue stain in the trees salvaged on this project, the heartwood and sapwood of each tree was scaled separately. The result is shown in Table II. The total board-foot content of these logs was 41,410, of which 16,910 board feet, or 41%, was stained sapwood, and 24,500 board feet, or 59%, was unstained heartwood. This percentage is merely an approximation, but it is believed that 45 to 50% would closely represent the usual amount of degraded sapwood in beetle-killed trees. However, if stained sapwood is considered a defect, the amount of cull in these trees would be practically 50% of their total volume. In this operation 16 trees (mostly 1926 attacks) were culled. Since these culled trees were of the blackjack variety, the percentage of total sapwood volume was relatively high. Had these trees been included in the salvaged stock, the percentage of stained sapwood would have been increased over the 41% shown in Table II.

Physical defect and decay, resulting in cull, do not usually occur in beetle-killed trees until after the first season of exposure. As previously pointed out, the principal causes of cull in these trees are checking, sap-rot and worm holes. These defects do not cause a great amount of loss during the first two seasons of exposure, but with the end of the second season the loss from these causes is heavy and continues to increase.

Checking results from the drying-out of the sapwood, attendant upon loosening and fracture of the bark. Except for slight checking of the extreme upper trunk this defect caused very little loss in the trees salvaged. However, after the second season of exposure it develops into a great source of loss, since checking extends to the center of most trees affected.

A negligible amount of loss resulted from worm holes and was not considered in the trees salvaged. The insects responsible for this form of defect do not attack the trees until after they have died as a result of barkbeetle attack. The rate of development of the more important ones is slow, so that the damage is not great until after the second season.

The greatest source of cull was sap-rot, which becomes pronounced in trees which have stood longer than one season after death. Of the total volume killed on the logged area during the two years preceding logging, 19.5% was culled because of sap-rot. The amount culled from each seasonal period of attack is shown in Table I. The greatest proportion of this loss occurred in trees which had been exposed for the longest period, or those killed by the summer brood of 1926. Table I shows that there was no loss from sap-rot in the trees killed during the last attack period immediately preceding logging; but in the attack period preceding this there was a loss of 13.5%, which increased to 83.3% in trees killed during the first attack period of 1925, two years previous to logging. These percentages of loss show that the amount of cull resulting from sap-rot increases with the duration of exposure following the death of the tree.

In young, thrifty trees with wide sapwood, sap-rot, by amounting to 80% or more of the gross volume, usually causes the loss of the entire tree. This is brought out in Table I, which shows that of the total 47 trees killed on the logged area 16, or 44%, were culled and no attempt was made to salvage them. These culled trees were small, thrifty blackjacks with wide sapwood, which was affected by sap-rot.

From the foregoing discussion it is apparent that the rapid decay of the sapwood is responsible for the greater part of the cull of beetle-killed trees. In the operation studied no attempt was made to salvage trees exposed for more than two years after death, because older trees were commercially a complete loss through decay.

SUMMARY

During the past fifteen years continued barkbeetle epidemics in the yellow pine forests of the western United States have resulted in the loss of many thousands of merchantable trees in these stands.

The removal and salvage of these trees is desirable because of silvicultural reasons and to conserve the natural forest resources. The salvage of this stock is economically practicable and its utilization possible under present lumber standards.

So far only a few attempts have been made to salvage beetle-killed timber. Very little data of a useful character have resulted from these operations.

A small sawmill operation in southern Oregon during the summer period of 1926 made possible a study of the salvage possibilities of beetle-killed western yellow pine.

The logging of the beetle-killed trees was accomplished by the same methods employed with the green timber and was done at the same time. It was found that the cost of logging these trees was 20% less than the cost of logging green timber. This was due to a partial seasoning of the trees before they were felled.

The date of the death of each beetle-killed tree on the logged area was known from previous cruises of the area. From these data the duration of exposure between death and milling was determined.

The principal causes of deterioration of beetle-killed trees is blue sap-stain. This is followed by checking. Later the development of fungi results in decay of the sapwood, and still later wood-borers damage both heartwood and sapwood. Sap-stain develops very soon after beetle attack and penetrates the entire sapwood by the end of the first season of exposure. The amount of sap-stain is dependent upon the volume of sapwood in each tree. In the trees salvaged it amounted to 61% of the entire volume. Sap-stain degrades the stock affected but does not result in cull.

Beetle-killed trees do not deteriorate greatly during the first two seasons, but after the second season they decay with extreme rapidity, so that by the fourth or fifth season the sapwood is a total loss commercially and the heartwood badly checked and worm-eaten.

Wood-borer damage develops slowly during the first two seasons, but thereafter is a defect of considerable importance.

The rate and amount of deterioration and decay of beetle-killed trees is proportionate to the length of exposure between death and salvage. In this operation it was found that trees killed more than two seasons prior to logging were unmerchantable. Of the total trees killed on the logged area during the two seasons previous to logging, 66% of the number were salvaged and 80.5% of their volume utilized. This volume included lumber degraded by sap-stain and checking, which amounted to 61% of the volume logged.

The source of the greatest amount of cull was sap-rot, which amounted to 19.5% of the gross volume. Included in this percentage is a slight amount of cull from checking and breakage.

The beetle-killed timber was sold on a gross-scale basis at 35% less than the green-pine rate. Practically the entire merchantable volume of each tree was utilized. The sawn stock was either used for stickers in the stacking yards or sold as box and for siding.

TABLE I

NUMBER OF TREES KILLED BY BEETLES IN 1926 AND 1927 ON LOGGED AREA AND NUMBER AND VOLUME SALVAGED FROM EACH SEASONAL LOSS

Killed on Logged Area			Number of Trees and Volume Salvaged					
Year & Season Killed	Total Number Trees	Total Volume B.F.	Total Scale in Board Feet Trees, Volume & % of Totals				Heart Scale in Board Feet	
			Trees	Percent	Volume	Percent	Volume	Percent
1926S	9	8,110	5	55%	3,870	47.7%	1,930	50%
1926W	18	14,340	8	44%	10.490	73.2%	6,600	63%
	27	22,450	13	48%	14,360	64. %	8,530	60%
1927S	11	14,230	9	82%	12,300	86.4%	7,520	61%
1927W	9	14,750	9	100%	14,750	100. %	8,450	57%
	20	28,980	18	90%	27,050	93.3%	15,970	59%
Totals	47	51,430	31	66%	41,410	80.5%	24,500	59%

TABLE II

TOTAL VOLUME AND HEART VOLUME IN BOARD FEET
OF KILLED YELLOW PINE KILLED BY D. BREVICOMIS

Tree Number	Season Killed	Diameter of Butt Log	Number 16-ft. Logs Salvaged	Total Scale in Board Ft.	Heart Scale in Board Ft.
1	1926S				
1	1926S	14	3	290	130
2	1926S	14	3	240	110
3	1927W	34	5	2,980	2,080
4	1927S	29	5	1,570	890
5	1927W	27	6	1,810	1,040
6	1926W	22	5	1,210	630
7	1926W	24	3	760	480
8	1926S	23	4	690	530
9	1927S	28	5	2,160	1,420
10	1927S	27	4	1,250	580
11	1927W	29	4	1,500	1,020
12	1926W	26	5	1,230	580
13	1926S	25	5	1,000	510
14	1926S	25	7	1,650	850
15	1926W	30	6	2,910	1,920
16	1926W	25	6	1,620	890
17	1926W	20	3	650	340
18	1927S	15	3	310	130
19	1927S	26	5	1,130	750
20	1927S	32	4	2,090	1,500
21	1927S	34	5	1,840	1,390
22	1927S	23	4	970	430

TABLE XI (concluded)

23	1927W	22	5	970	570
24	1927W	23	6	1,490	710
25	1927W	25	4	1,190	630
26	1927S	26	3	1,200	650
27	1926W	22	3	730	450
28	1926W	32	4	2,610	1,890
29	1927S	22	4	980	430
30	1927W	23	3	890	470
31	1927W	25	4	1,490	930
Totals				41,410	24,500
Average Tree		25.6	4	1,336	790

DESCRIPTION OF PLATES

Deterioration of standing western yellow pine trees killed by the western pine beetle (*Dendroctonus brevicomis* Lec.)

Plate 1 - External Characters.

A. Group of trees killed by the 1928 winter brood of the beetle. This photograph was made about 90 days after the trees were attacked. Winter broods do not leave the infested trees during the same season of attack but emerge the following spring. The external characteristics of beetle-killed trees at this stage are: fading to red foliage, which is still mostly retained; and tight, unbroken bark. The trees lose these characters after the first year and thereafter deteriorate at a rapid rate.

B. An individual tree of the preceding group opened to show conditions under the bark. Such an examination will reveal the infesting brood in various stages of development; intact bark, which is more or less tight to the bole of the tree; and slightly blue-stained sapwood. Except for blue stain in the sapwood the lumber from such trees is free from defect.

Plate 1 - External Characters (concluded)

C. Photograph of the lower trunk of a tree killed by the 1925 summer brood of the beetle. This photograph was made in December 1928, approximately 30 months after the tree was killed, and shows the typical condition of trees at this stage of deterioration. The external characters of beetle-killed trees after standing through three growing seasons since attack are: complete absence of needles, black limbs and loose, fissured bark. The sapwood is almost always badly blue-stained, with well-developed rot under the outer annual rings. Another characteristic is deep checking of the sapwood which sometimes extends into the heartwood. The heartwood, and more particularly the sapwood, is usually badly damaged by larval galleries, or "worm holes", made by the larvae of wood-boring insects. Exit holes from these galleries are shown at "a" and "aa". The salvage yield from trees in this stage of deterioration is very low and confined exclusively to the heartwood.

D. Cross-section of trunk of tree killed in 1926 by the summer brood of beetles, and windthrown in the fall of 1928. This cut, which was made at a height of 12 feet from the ground, shows all the sapwood badly blue-stained, which is a common condition at the end of the first season. Other than sap-stain, which degrades the lumber, this log had not deteriorated, since there was no checking or worm hole damage. Slight sap-rot had started at "a", though it had not advanced sufficiently to cause defect which would result in cull.

Plate 2. Internal characteristics of degraded stock from beetle-killed yellow pine trees.

A. Cross section from end of log of tree killed in the summer of 1926. This photograph shows the condition of the wood 19 months after the tree was killed. All the sapwood is deeply blue-stained, though no season checking had as yet occurred, since the bark remained intact on the entire log circumference. Aside from sap-stain no other defect is present. Such logs make good lumber, though it is slightly degraded in character on account of the blue stain. The percentage of salvage, if the blued stock is not not culled, is high and amounts to practically the full scale.

B. Sectional detail of sample shown in A. This cut shows the sound wood in both the heart and sap sections. Neither rot nor wood-boring-insect damage is present.

C. Section of vertical-grain board sawn from the heartwood of tree killed by beetles in the summer of 1926. While the wood is free from rot and insect damage, some blue stain had developed before milling, as shown at "a". This section is a sample of sound heartwood from a tree of which the sapwood was no longer merchantable.

D. Section of vertical-grain board sawn from the sapwood of a tree killed by beetles in the summer of 1926. This and the above section were milled in June 1928, two years after the trees were killed. Had this tree remained standing, the deterioration would have been rapid during the season following date of felling and salvage. Rot had already started, as is shown by the brown stain at "a". Blue stain was well developed and is shown by the

dark photographic rendering at "b". Two small worm holes are shown at "a", which in this case were made by the larvae of the California sapwood borer, Buprhis californica. This section is an average sample of stock from trees killed two years prior to milling. After four growing seasons of exposure, checking and decay render sapwood a complete loss commercially.

Plate 3.

A and B. Section of the outer sapwood of tree killed in 1926 by the winter brood of beetles. The tree was milled in May 1928; therefore one growing season had passed since it was attacked. Aside from blue-staining a minimum of deterioration had occurred. Small worm holes made by the larvae of the California sapwood borer are shown at "a". These holes, because of their minute size, are a defect of small importance as affecting the strength of the stock. The brood galleries of the western pine beetle, the cause of the death of the tree, are shown at "b" on the surface of the sapwood.

C. and D. Section of quartersawn sapwood from tree killed by the 1927 summer brood of the beetle. This section is only partially blue-stained, the lighter areas representing unstained wood. The vertical grain at the edge of the board at "a", Fig. D, shows both heartwood and sapwood. The light-toned strip at "b" is unstained heartwood. Except for the blue stain these sections had not deteriorated.